

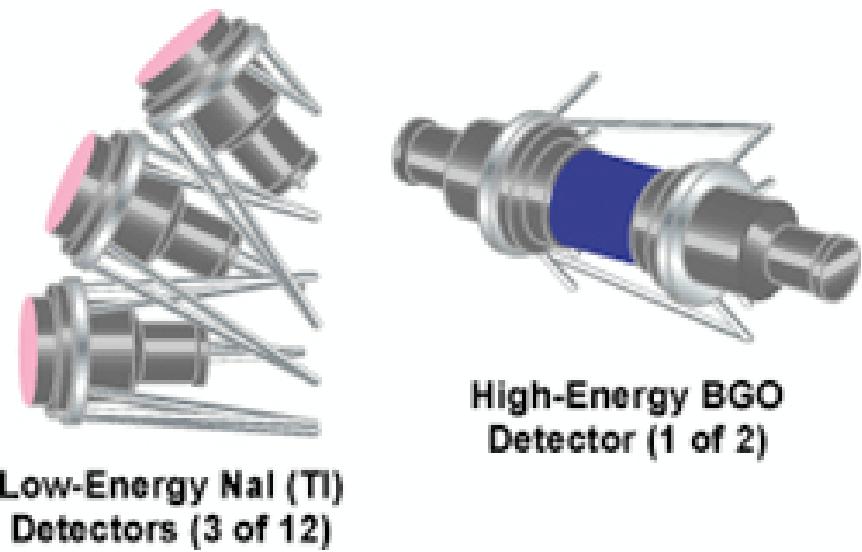
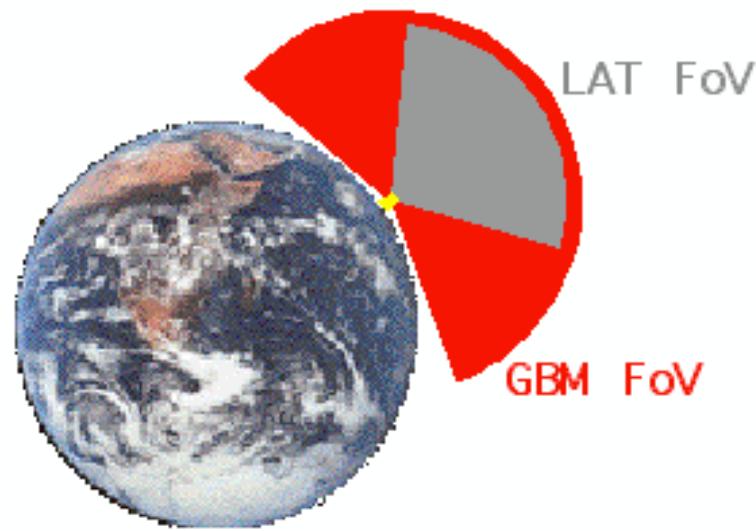
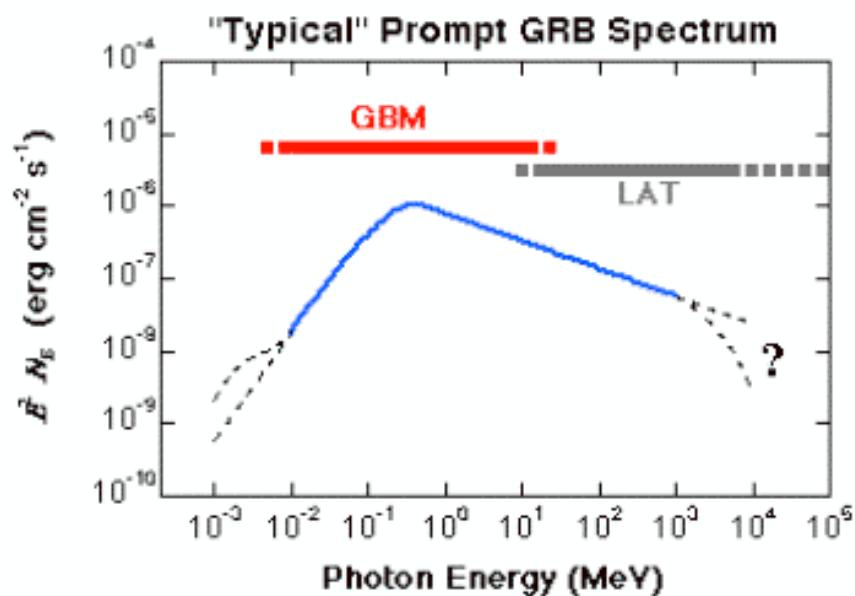
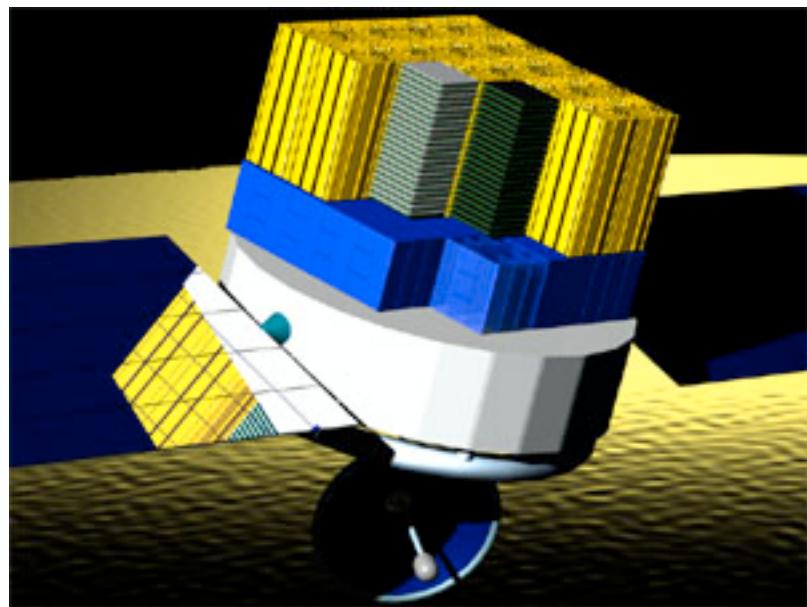
γ -ray bursts in the ... GLAST/GBM.... era:

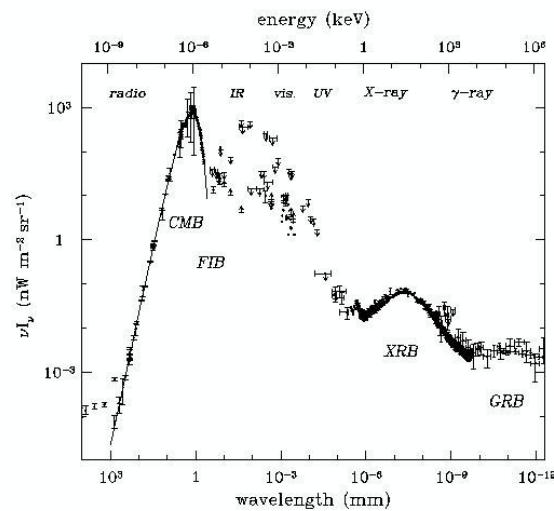
On the road to understanding

D. Hartmann

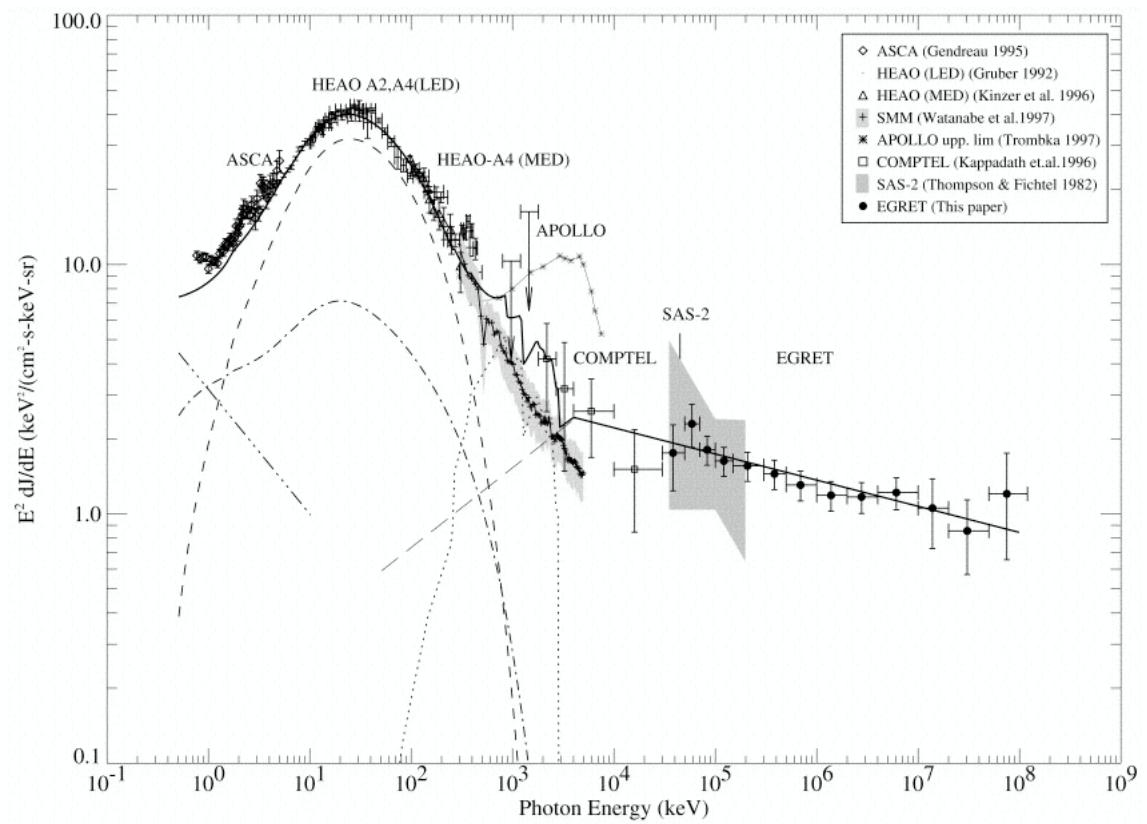
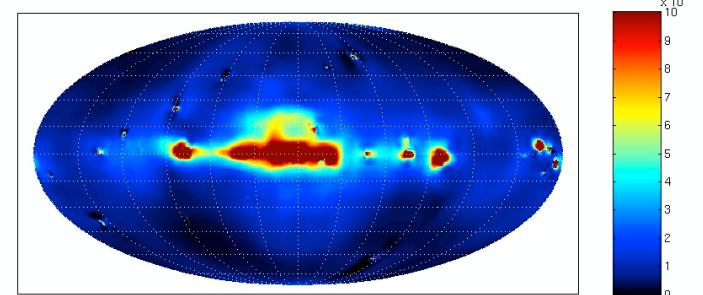
Department of Physics & Astronomy, Clemson University
Clemson, SC 29634: HDIETER@clemson.edu

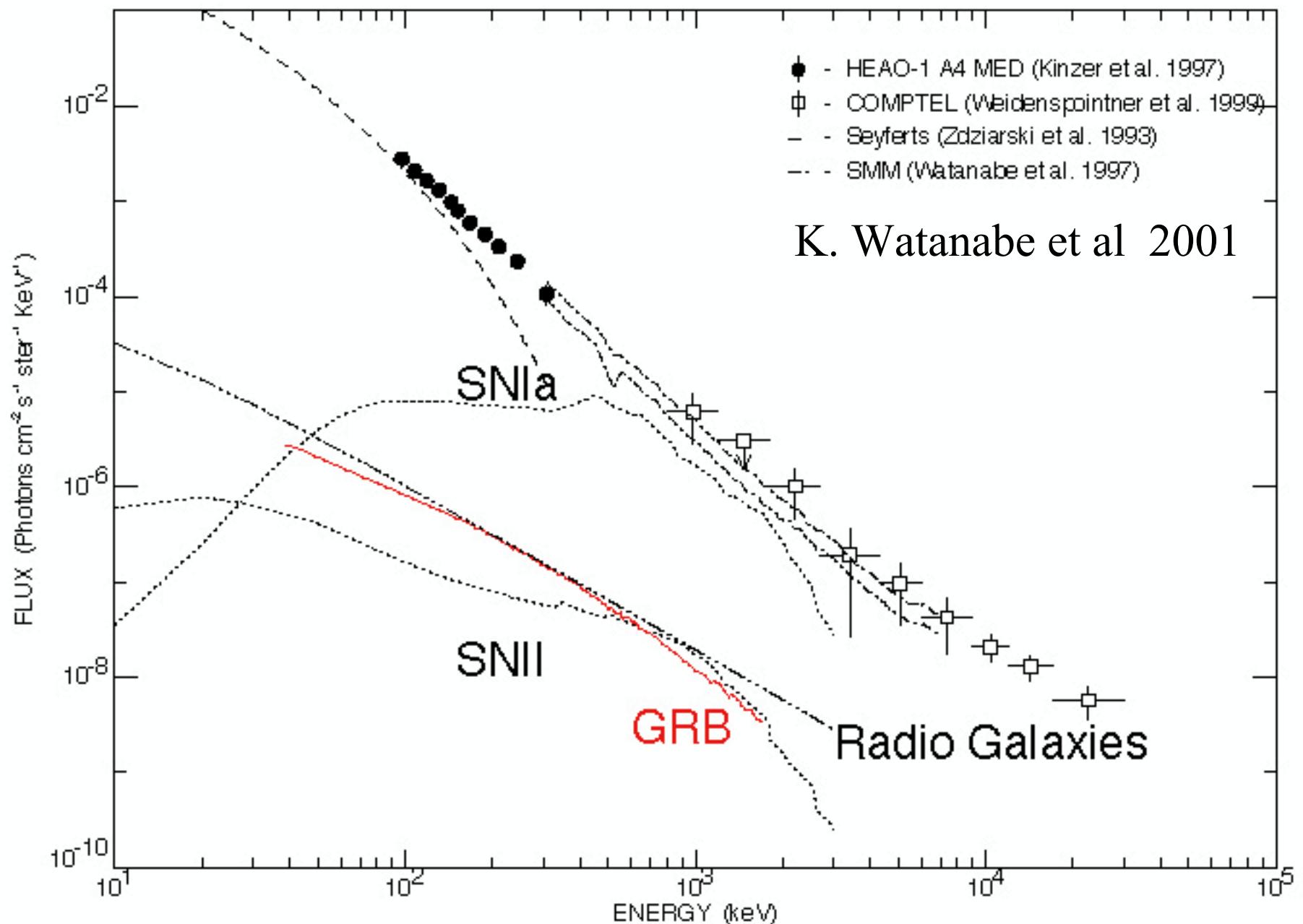
SWG meeting, Huntsville, AL, September 12-13, 2002





Background





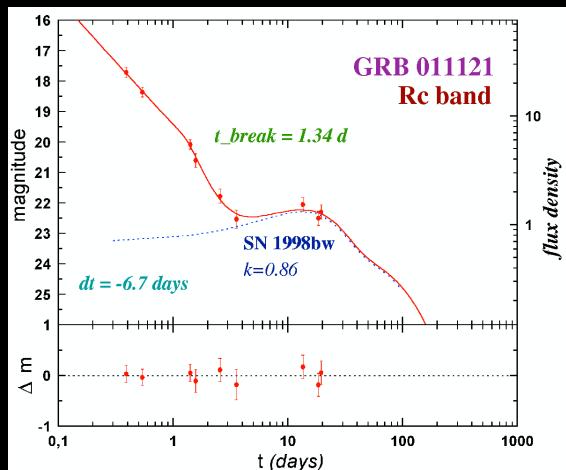
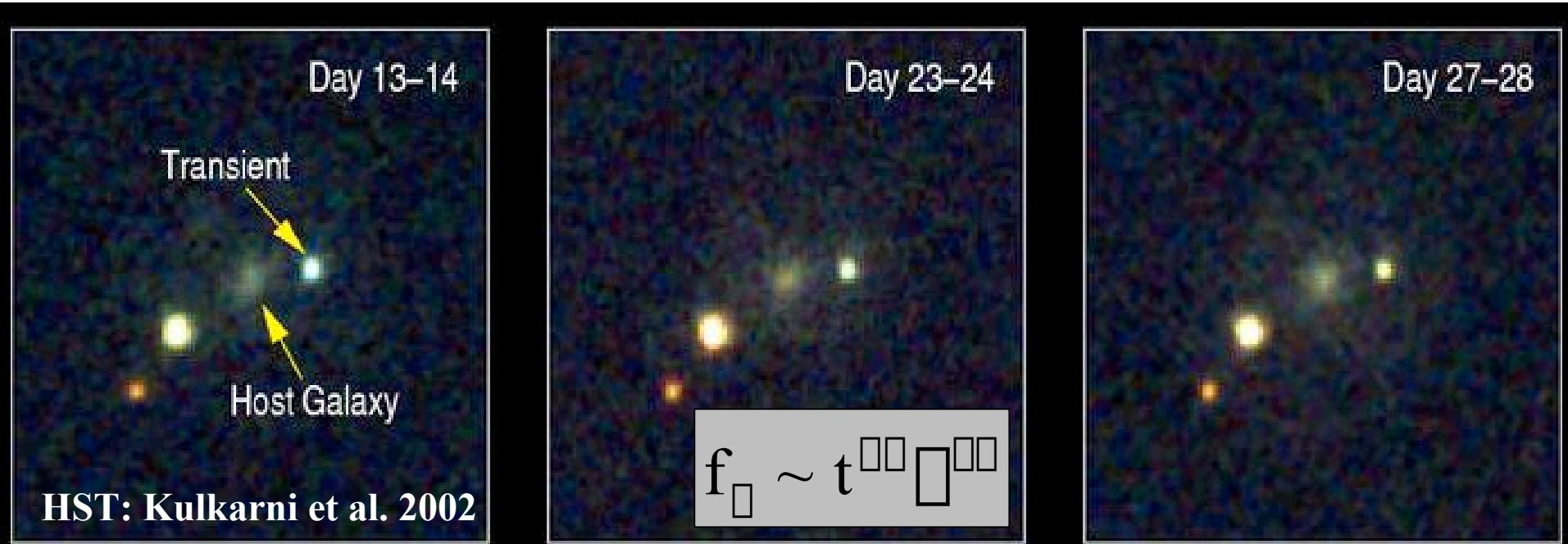
Paradigm Testing

$$R_{\text{rb}} \sim \text{SFR}$$

long duration: collapsars

short duration: mergers

C. Fryer, S. Woosley, D. Hartmann 1999, ApJ 526, 152



Greiner et al. 2002

Afterglow Physics

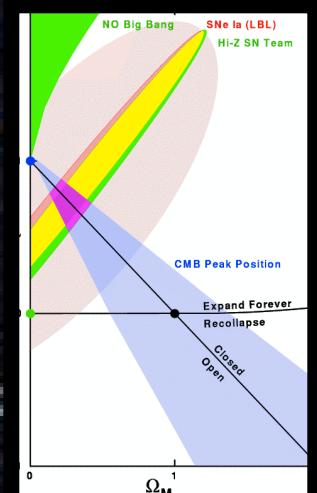
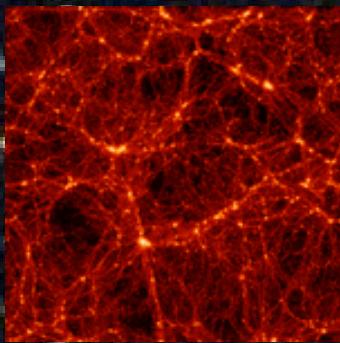
jet breaks □ beaming angles □ energetics

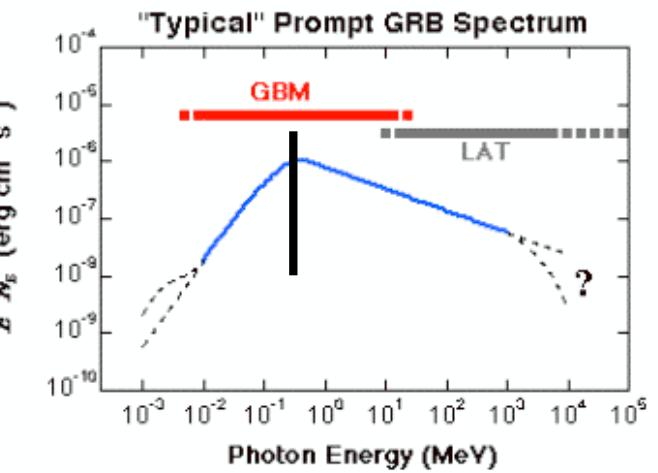
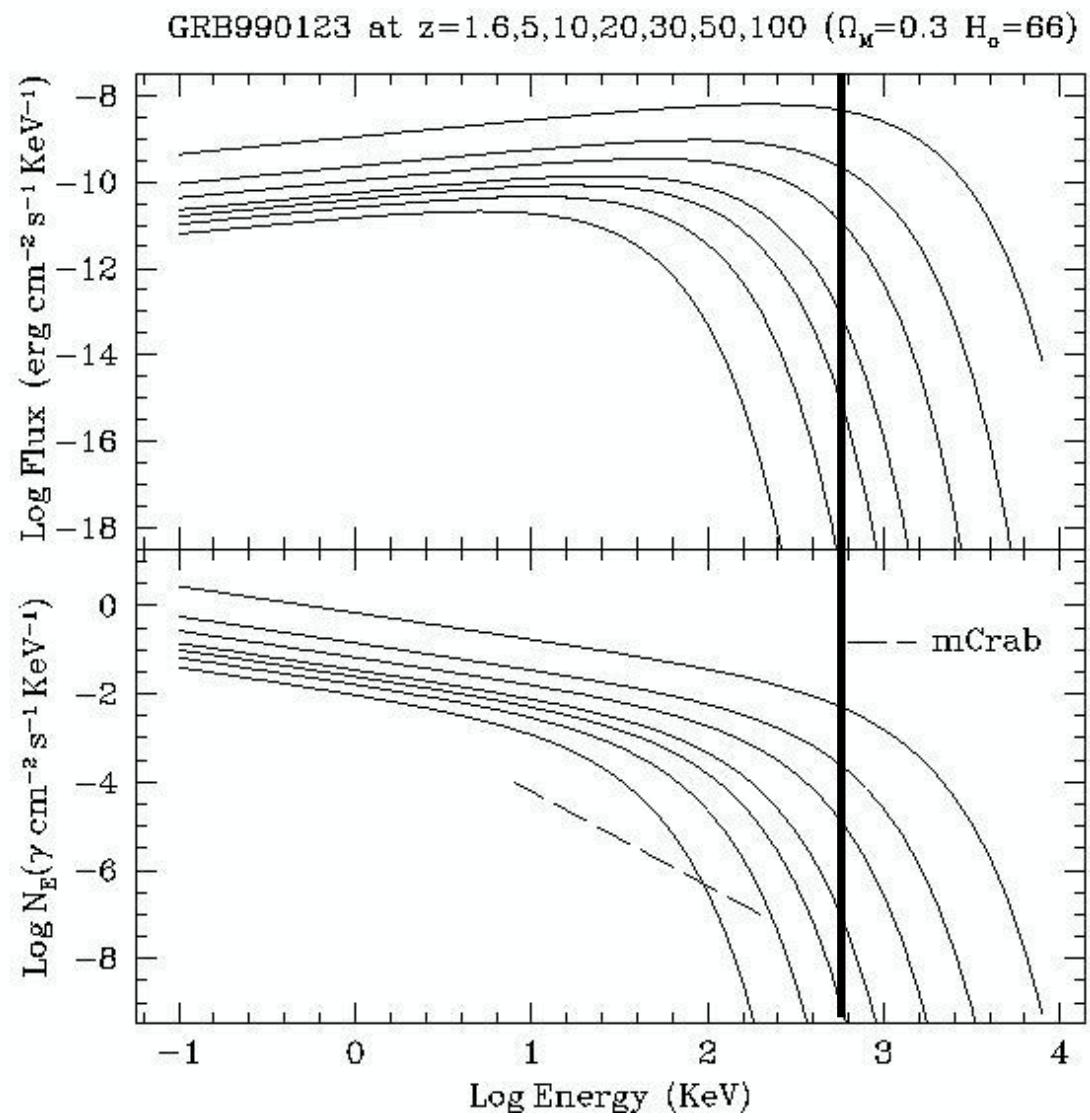
□-□,p: □rb environment & e-acceleration

Properties of associated “hypernovae”

97ef, 97ey, 98bw, **01ke**, 02ap

Cosmology with GRBs





$z=18.2$

Tracing the early universe

QSOs: $z \sim 5$

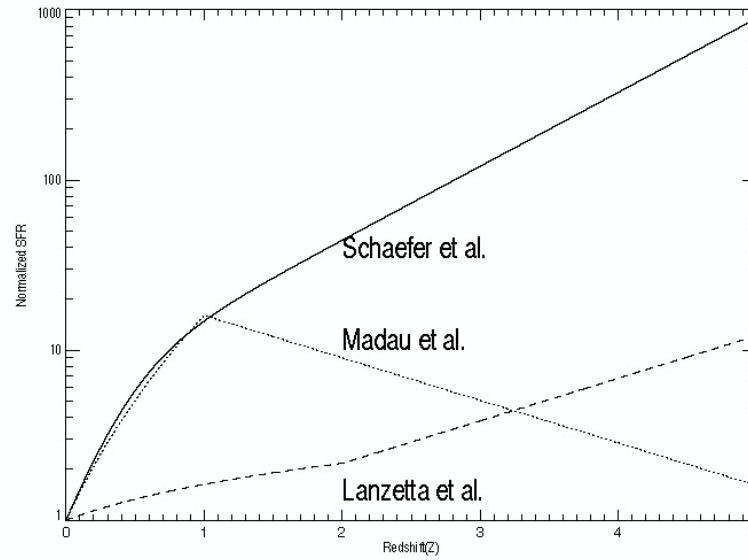
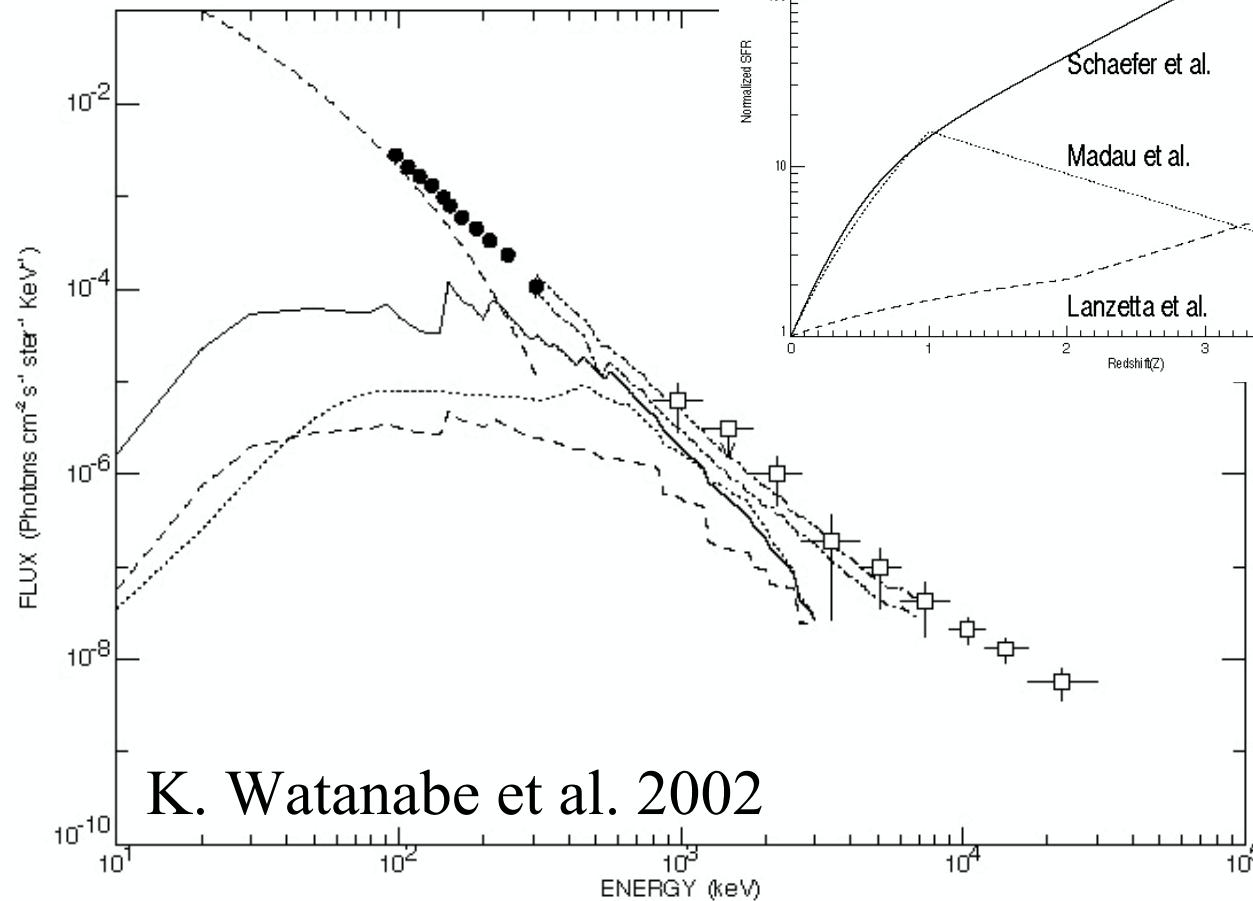
galaxies: $z \sim 6 \sim z_{\text{reionization}}$

GRBs: $z \sim 4.5$

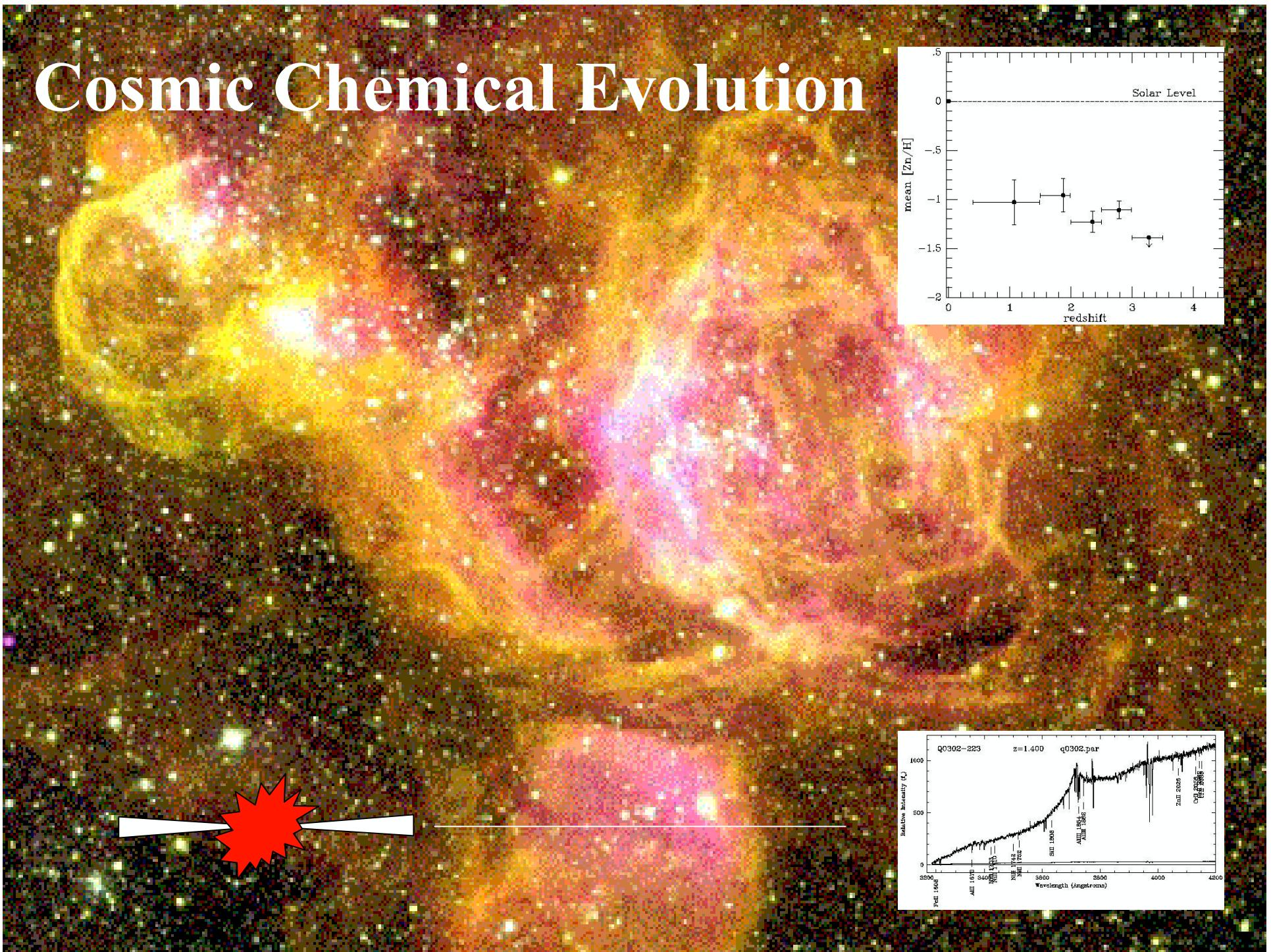
Pop III stars: $z \sim 10-20$

T. Abel et al

■ rbs ■ The Cosmic Star Formation Rate

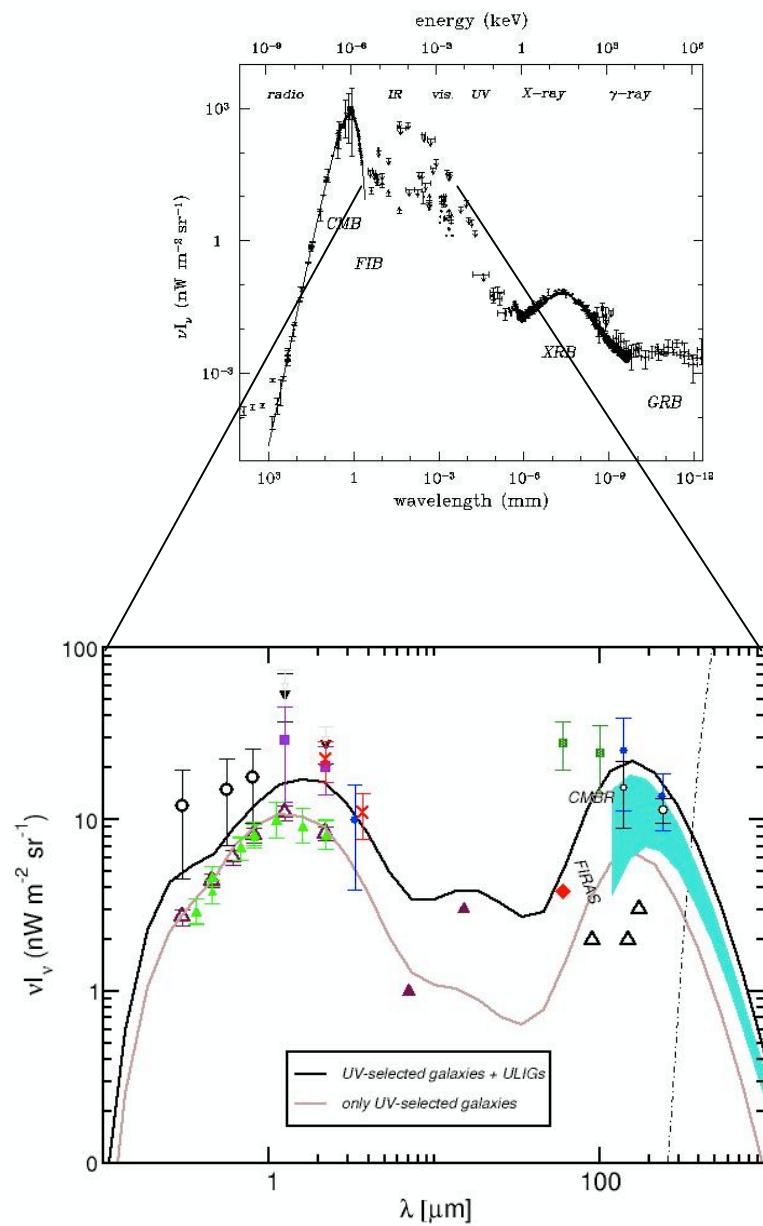


Cosmic Chemical Evolution

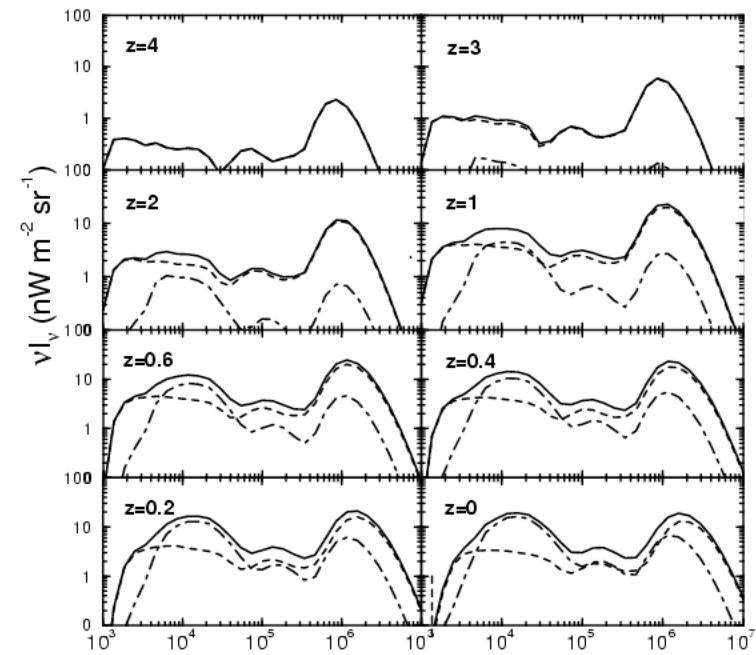


The evolving cosmic radiation background

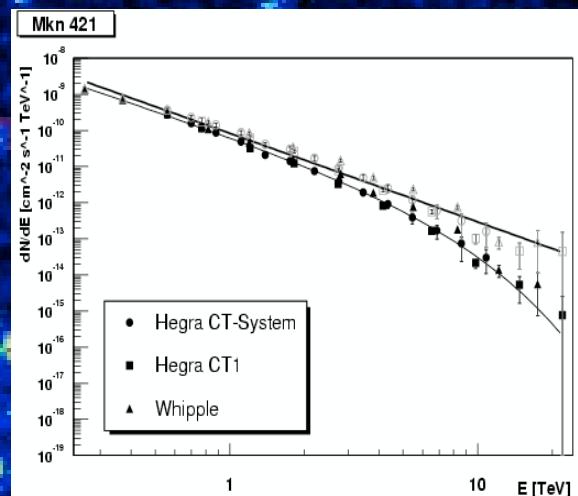
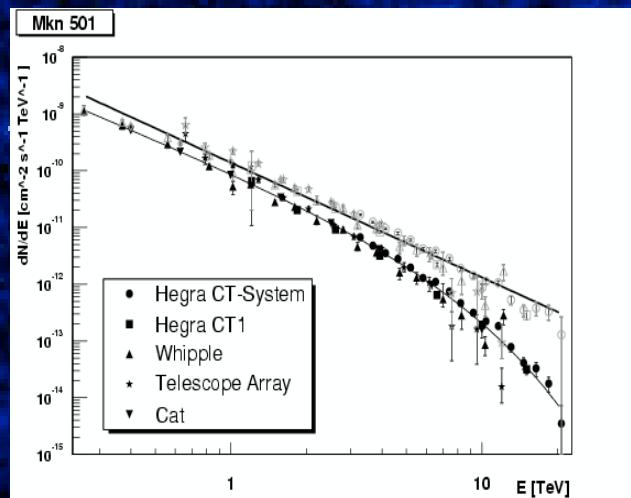
□ optical depth at $E \sim \text{TeV}$



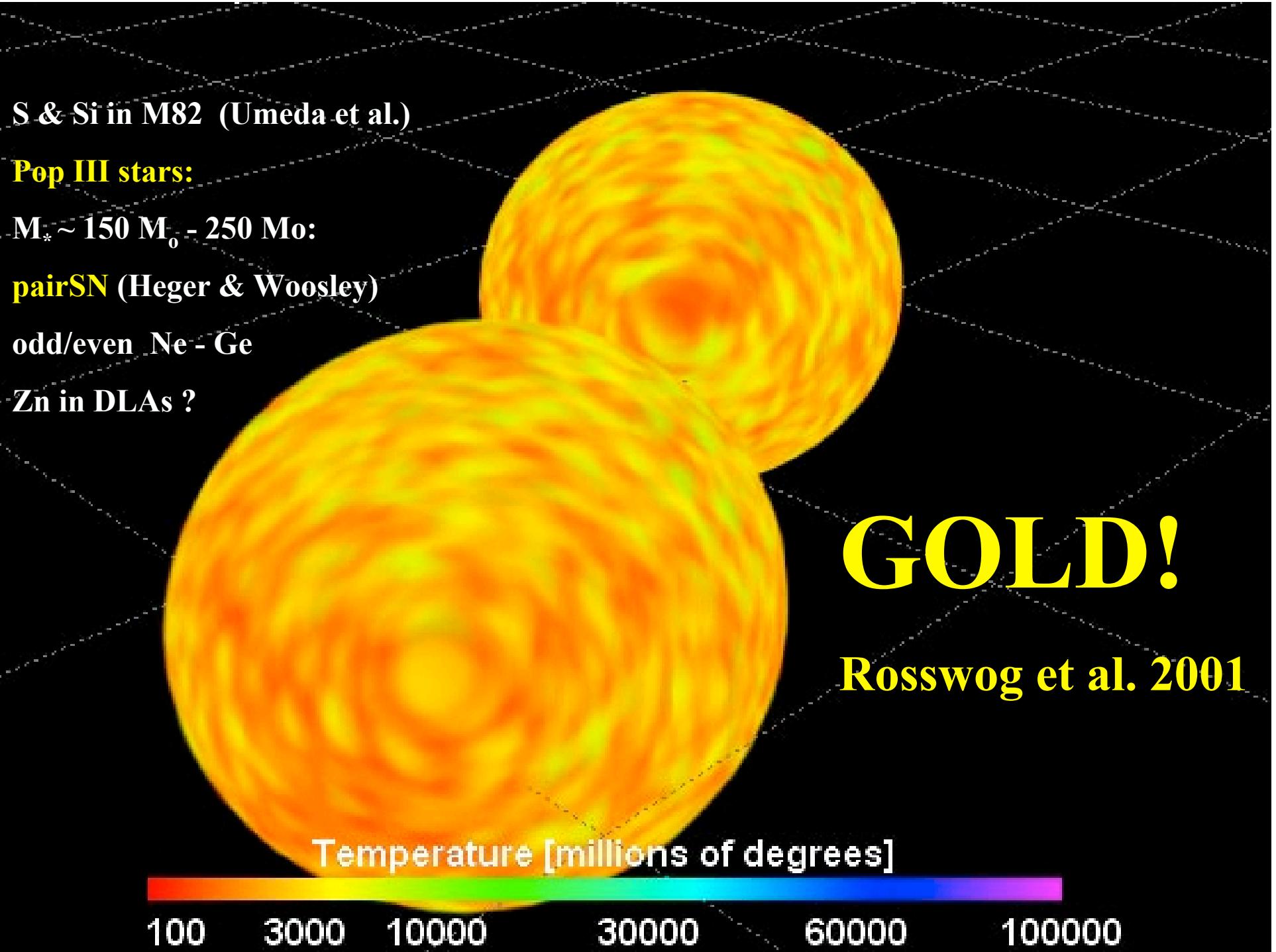
Kneiske, Mannheim, Hartmann 2002, A&A 386, 1



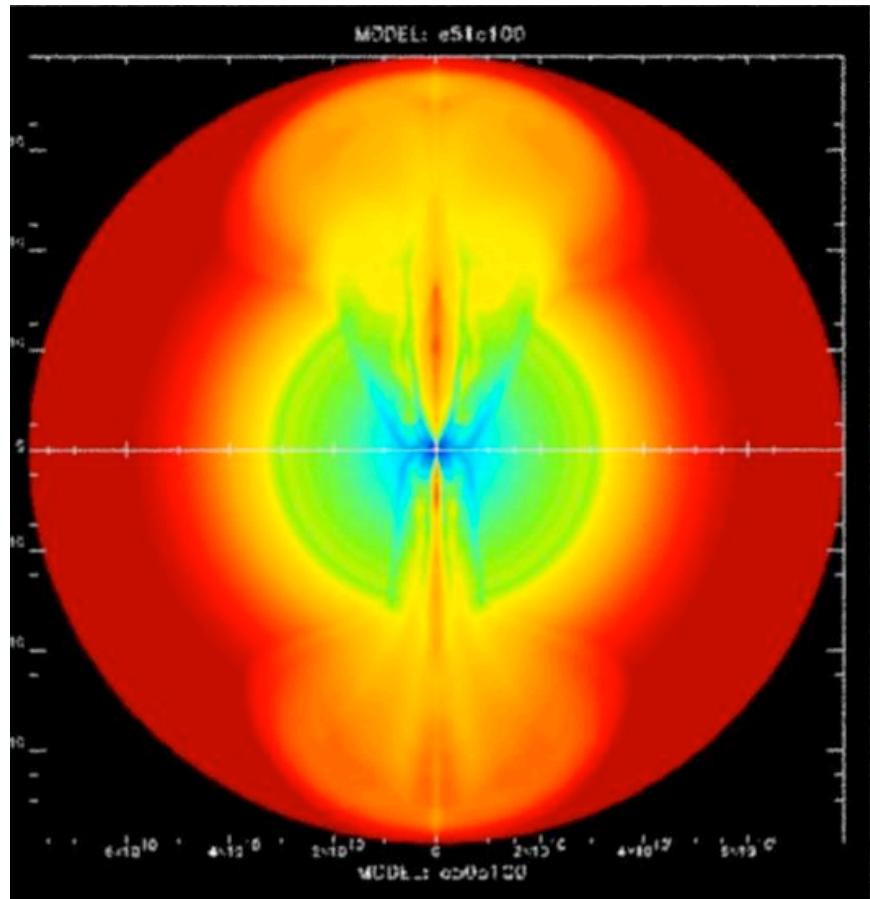
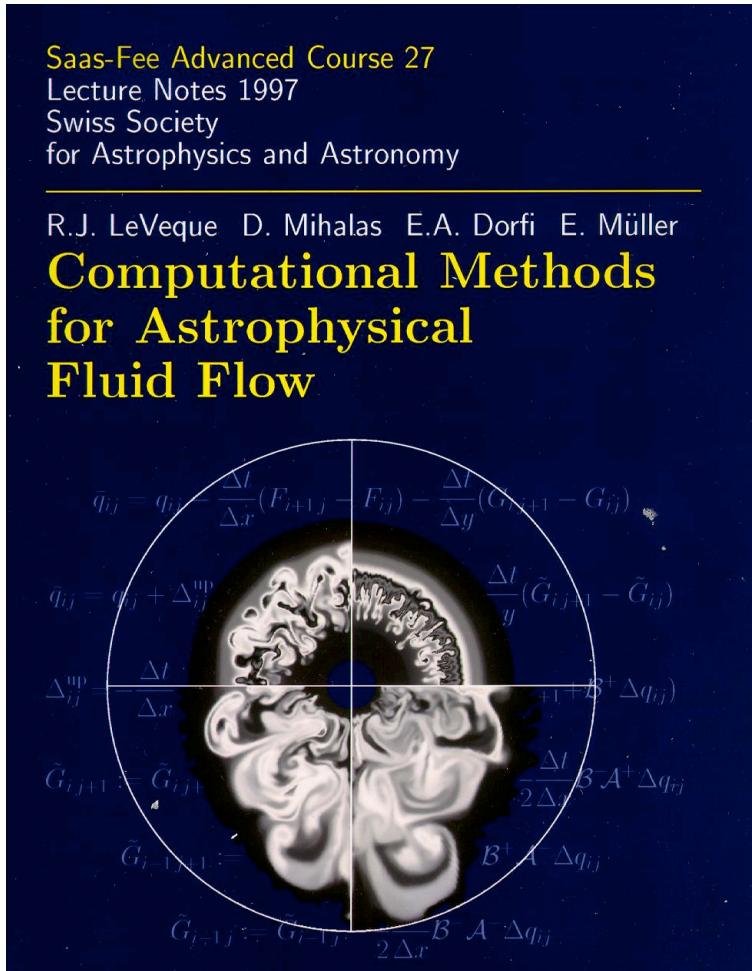
High energy absorption of GRB spectra



Kneiske, Mannheim, Hartmann

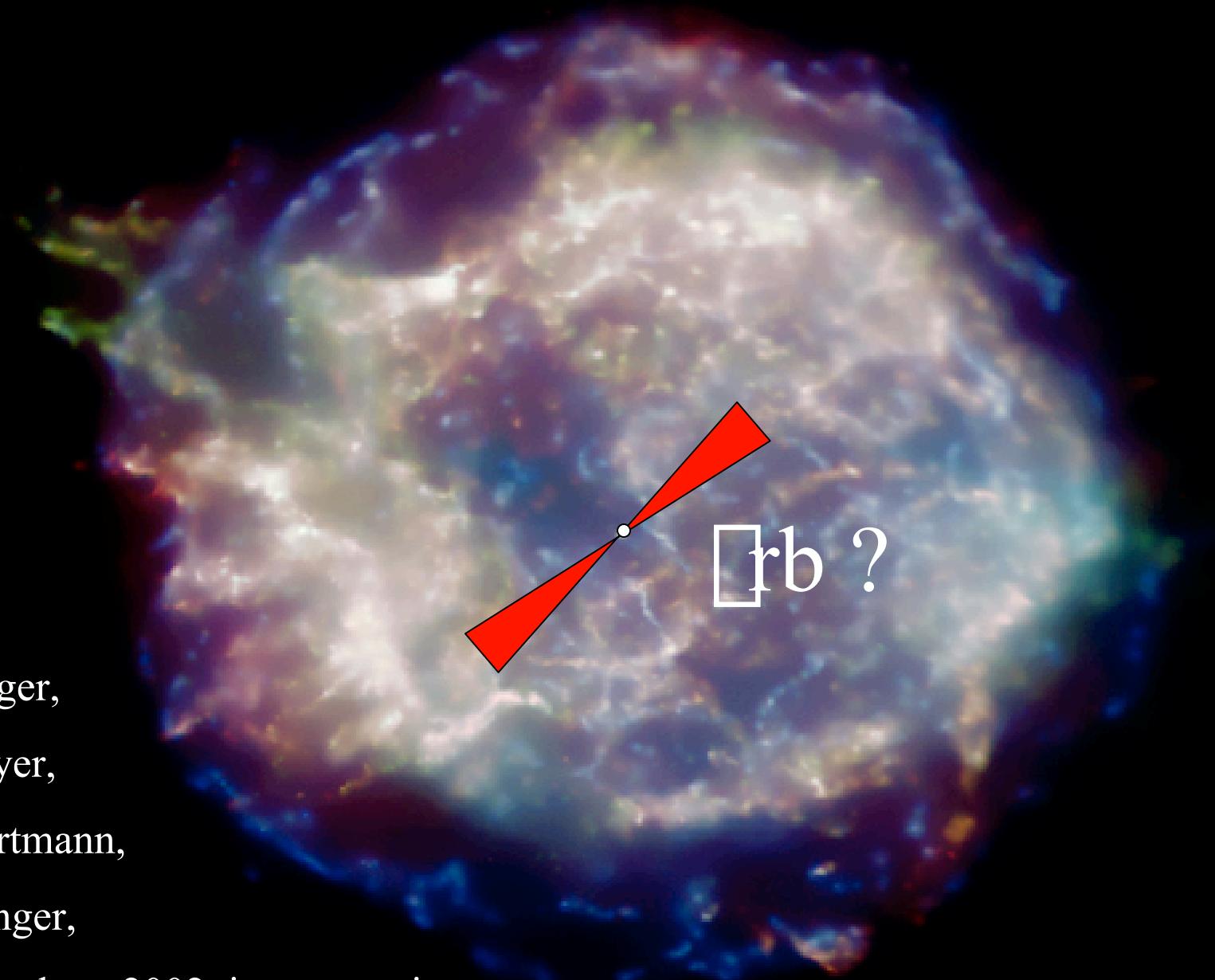


THEORY



Relativistic Hydrodynamics
Special & General Relativity

How massive **single** stars end their life



A. Heger,
C. Fryer,
D. Hartmann,
N. Langer,
S. Woosley 2002, in preparation

The BHAD central engine

$E_0 \sim 10^{52}$ ergs:

SN

GRB

AG



$\square \ll 4\square$

A unified model

$R_{\text{GRB}} \sim 1\% R(\text{SN})$

GRB \sqcap SN I

not: SN \sqcap GRB

$t(\text{outflow}) > t(\text{GRB})$



GRB/SN diversity

e.g. hard X-ray flashes (Heise et al.)

Collapsars 101 - Woosley 1993,

Rotating massive stars (no H envelope)

$$\dot{M}(Z(z))$$

Ang. Momentum: central BH with accretion disk (BHAD)

Jet formation (\square , BZ)

$$j(B) \square \text{Spruit}(2001)$$

collimated outflow, breakout,

$$j[\dot{M}(Z(z))]$$

$\square \gg 1$ if mass loading is low

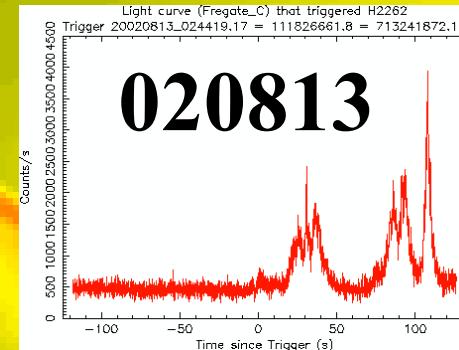
Standard $E_0(M_{BH}, M_{acc})$ - jet-SN shuts off accretion

At least three progenitor routes

Detailed predictions to test the model remain TBD

Light Curve Structure

Variations of energy input where the jet is born, do not manifest themselves in the GRB lightcurve



Jet-Star Interaction:

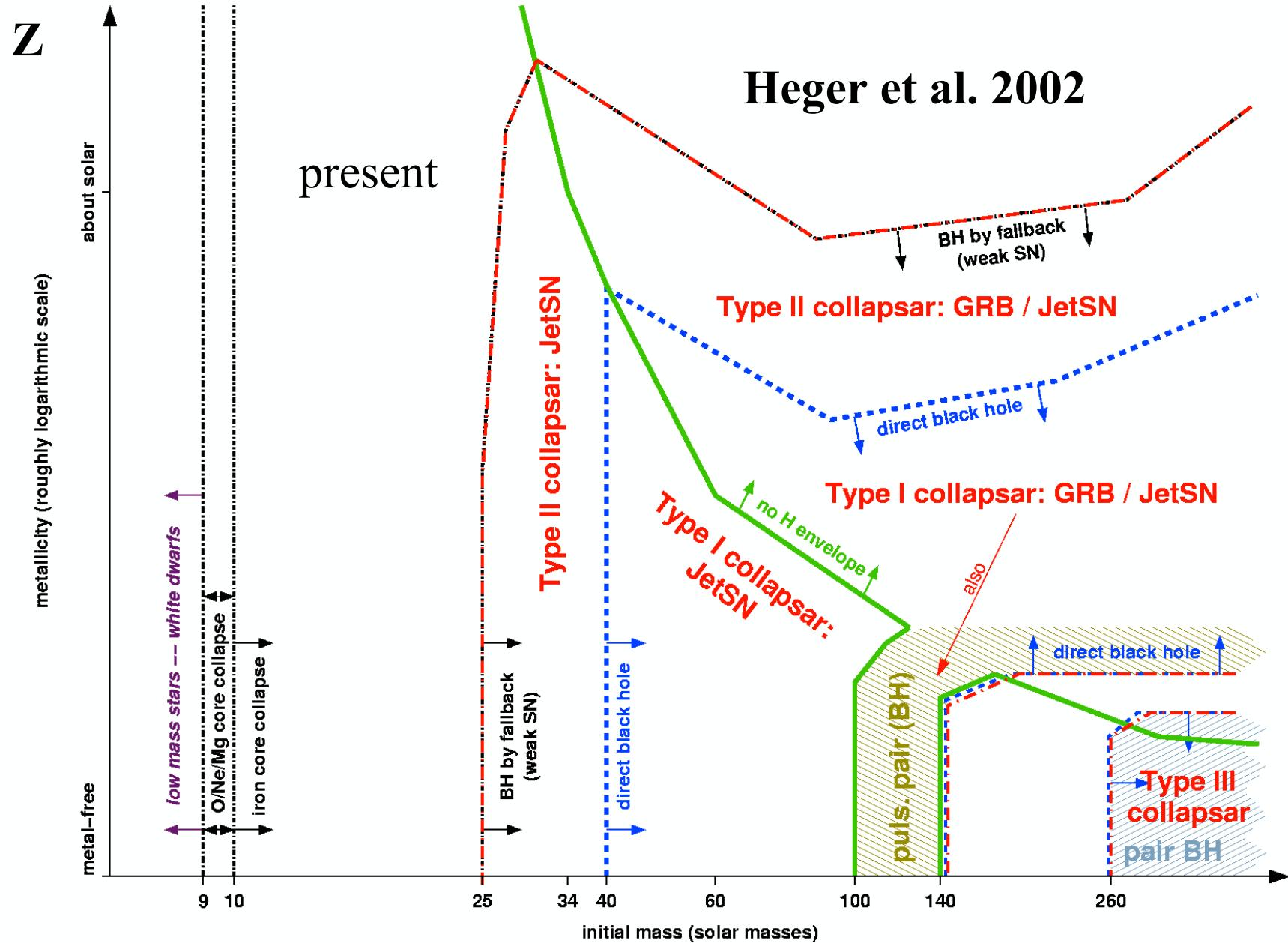
Relativistic KH Instability

- baryon loading of the flow
- Lorentz factor spectrum

$$\text{Var} \sim \text{KH} \sim \frac{A_{\text{jet}}}{V_{\text{jet}}} \sim \square_{\text{jet}}^{\perp 1} \sim \text{Lum}$$

Three Types of Collapsars

- CI - $M(He) \sim 10\text{-}40 M_\odot$: prompt BH formation, no successful shock after cc, $M_{BH} \sim \text{few } M_\odot$. $dM/dt \sim 0.1 M_\odot/\text{s}$, $\Box t \sim 10 \text{ s}$, temp. proto-NS formation = $f(\text{eos})$, \Box -flux smothered: low Z reduce dM/dt , and thus increases $M(He)$
- CII ~ CI - Delayed BH formation (fall back) with $t \sim \text{min}\text{-}hrs$; similar parameters
- CIII - Pop III stars: $M > M_{\text{crit}}(\Box) \sim 250 M_\odot$, BH mass $\sim 100 M_\odot$, $dM/dt \sim 0.1 M_\odot/\text{s}$ for $10(1+z) \text{ s}$

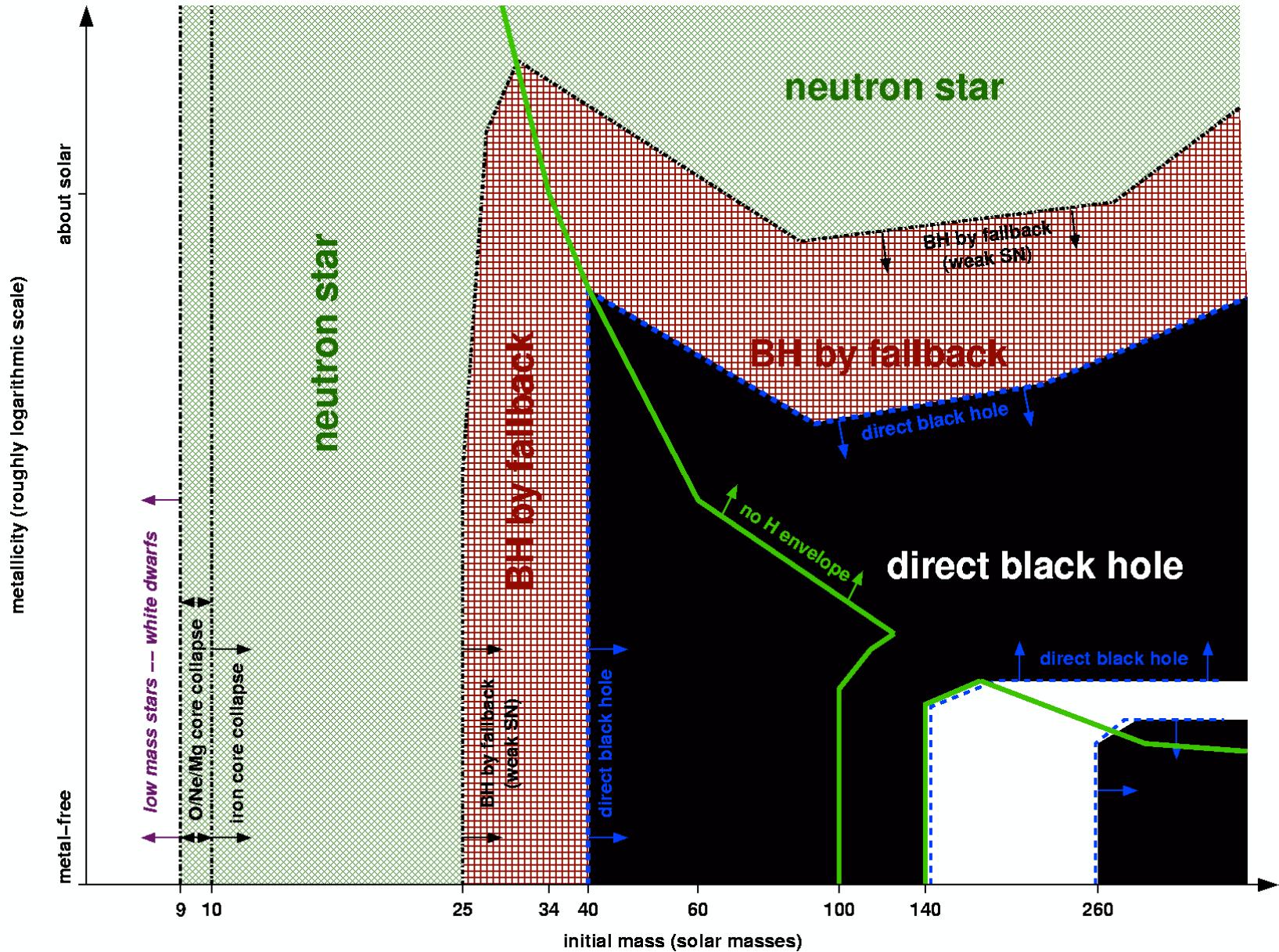


$z=18.2$

Star formation in the early universe is believed to favor very massive stars

(biased IMF)

**GRB type-ratio and
GRB rate/SFR-ratio change with
metallicity-(AMR)-redshift**





Conclusions

Once you have seen one GRB,
... you have seen one GRB !